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USING OF NEW NARROWBAND WAVEFORMS TO ENSURE PROPER OPERATION OF COMMAND AND COMMUNICATION SYSTEMS

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ABSTRACT

Accomplishment of basic services implementation with specific quality is one of the main challenges of the command and communication systems for modern maritime safety and defense. The specificity of the marine environment imposes the use of narrowband HF (High Frequency) and VHF (Very High Frequency) radio communication devices which are capable to implement IP transmission. This paper presents the requirements for the HF and VHF radio systems according to the IP protocol requirements. At the beginning basic properties of narrowband HF and VHF waveforms in context of their operational scenarios has been described. Then results of experimental research (implementation of narrowband services — voice and data) has been presented. Finally further research directions with contribution of the authors, in NATO working groups related to the development of NBWF (Narrowband Waveform) for coalition communication has been presented.

Key words:

LOS, BLOS, NBWF, RKP-8100, RSSI, BMS,VHF, UHF, HF.

Research article

INTRODUCTION

The activity of warships on the sea waters results from the need to protect the area of defense responsibility of the state and polish coalition commitments. The tactical data exchange systems are the necessary equipment of every warship and land infrastructure connected to staffs and command posts. Because of the fact that the equipment of every warship and land infrastructure is based on narrow-band radio stations it is reasonable to use existed and installed radio stations. This proposal is especially justified because the exchange of antennas and equipment in mobile platforms is complicated, expensive and time consuming. Nowadays technical and organizational limits create therefore necessity to look for solutions that support tactical communications and enable marine operation on the base of existing HF/VHF equipment. In such a cause it is needed to consider technical solutions that meet the user demands and will allow the data exchange and meet the needs of future missions.

THE SPECIFICS OF COMMUNICATION SYSTEMS USAGE DURING MARITIME MANEUVERS

In case to specify the working (perform the specification/produce the specification) of the communication systems during the maritime operations two fields were identified for further analisys:
- classification of the data being exchanged;
- physical and logical relations between communicating objects.

Classification of the exchanged data

There are two perspectives, operational and technical in which the data exchanged during the maritime operations needs to be analized. Within both of the above the following types were recognized:

1. Operational perspective:
   - tactical situation data — location of detected and recognized objects above, on and under the water surface (including the data about mines);
   - tactical communication data — text messages exchanged between operators and stakeholders executing the mission;

   - command information — formalized text and binary reports containing information about the ongoing and already executed tasks.

2. Technical perspective:
   - binary data — witihn this type the aim is to achieve maximum information density per data unit; examples of this data type include messages and coding used in Tactical Data Links systems;
   - text data — data saved as a text code, for which high information density isn't crucial or for which contextual limitations are not obligatory or which allows transmission of additional information; examples of this data type include messages nad coding defined in OTHT-GOLD and AdaT-P2 standards;
   - slowly changing data — defined as data transmissed not more often than once an hour;
   - rapidly changing data — defined as data transmissed at least once every five minutes.

Classification of communication relations

Logical relations

Within logical relations data is being transmissed between:
- headquarters <-> ship (commanding the ship);
- ship <-> ship (commanding the group of ships).

Physical relations

LOS (Line of Sight):
- headquarters (command center) <-> radio access point;
- radio access point <-> ship;
- ship <-> ship.

BLOS (Beyond Line of Sight):
- headquarters (command center) <-> radio access point;
- radio access point <-> ship.

The above analisys of the data and the relations (between communicating objects) indicates that for securing maritime operations narrowband HF/UHF (*High Frequency/Ultra High Frequency*)radio stations can be used to provide primary services of a specified quality.

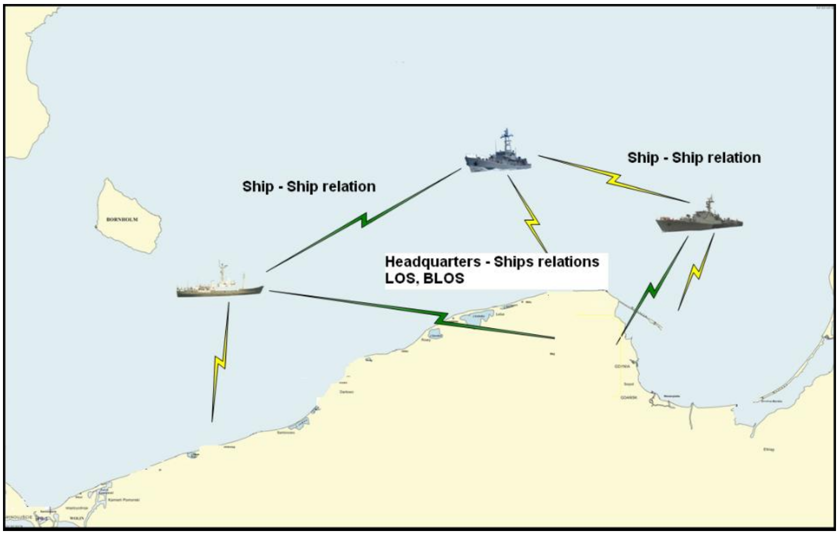

Fig. 1. Example of a relations in maritime radio network

REQUIREMENTS FOR DATA EXCHANGE SYSTEMS

While creating the data exchange system it is needed to consider the availability of protocol layers, cryptographic protection and protocols that support services demanded by users. It is needed to pay attention to the fact that on the warship and inside the land infrastructure the net IP installations of solutions are additionally aided by IPSEC cryptography. Protocols that support services demanded by users are:

- **Link11/16/22** — the real time data exchange related to ally, neutral and foe objects located on land, in air, on the sea and under water;
- **OTH-T GOLD** [4] — the message format that is compliant with OPERATIONAL SPECIFICATION FOR OVER-THE-HORIZON TARGETING GOLD REVISION D (2000) — the transmission of tactical situation messages, textual messages, graphical layers and the generation of automatical (periodical) and manual routes (used between C2I Navy System Łeba nodes to exchange tactical information);
- **ADaTP-3** [3] — the message format that is used by NATO to exchange formalized messages compliant with APP-11; it is possible to generate selected messages using specialized forms.

BASIC PROPERTIES OF NARROWBAND HF AND UHF WAVEFORMS

Primary goal of an NBWF standard is to provide mutual radio transmission between onsore objects (althought usage of this standard for communication between flying and maritime objects is also considered) with a throughput between 20 and 82 kbps, in a 30 to 512 MHz band, with a 25/50 kHz radio channel width. Radio station of this type deliver the following services:
- multicast voice;
- IP data services;
- unrestricted services, often called 'unrestricted data services', those can be used both for audio and data tansmissions;
- dedicated broadcasting packet transmission service, suitable for FFT (Friendly Force Tracking);
- selective call.

There are following NBWF standarisation documents:
- Stanag 5630 (narrowband waveform for VHF/UHF radios — head Stanag);
- Stanag 5631 (narrowband waveform for VHF/UHF radios — physical layer standard and propagation models);
- Stanag 5632 (narrowband waveform for VHF/UHF radios — link layer standard);
- Stanag 5633 (narrowband waveform for VHF/UHF radios — network layer standard);
- Stanag 5634 (narrowband waveform for VHF/UHF radios — IP access to half duplex radio networks).

Polish RKP-8100 radio station is an example of a successful implementation of the NBWF standard. This solution contains an algorithm for every layer defined in the NBWF model. NBWF ed. 1 doesn't include standards for hopping capability. For this reason OBR CTM S.A. has developed his own standard with specific parameters as listed bellow:
1. Layer TRANSEC — hopping 320 hop/s full band.
2. Layer Carrier — QPSK modulation with z channel equaliser in 30–512 MHz, channel 50kHz, access to the channel CSMA (VPOD) or TDMA (JPGID).
3. Layer AIE — algorythm AES-256.
4. Layer Radio Mgmt. & Control — SNMPv3, http, telnet, RS232.
5. Layer Routing Information — implementation IPv4 — standard routing with QoS — STANAG 4691 Annex A (MANET).

6. Layer Comsec — cooperation with external SCIP.
7. Layer Voice/Low Data Rate — voice — vocoder MELP 600/1200/2400, Low Data Rate — xmpp, smtp, IP/UDP.

To ensure proper operation and protection against self-induced and hostile interference there is a number of guidelines specified in the standard to be implemented in a modern narrowband HF radio stations. Table below lists fundamental recommendations that the modern systems of communication working in HF band need to comply with.

Tab. 1. Lists of standards implemented in RKP-8100

Standard Name	Description
STANAG 4285: 75–3600 bps	Modem HF for broadcast
STANAG 4529: 75–1800 bps	Modem KF for channel less than 3 kHz
STANAG 4415: 75 bps	Robust Modem HF for strongly disturbed environment
STANAG 4539: 75–12800 bps	Modem HF with ARQ
MIL-STD-188-110A/B/C: 75–19200 bps	Modem HF with ARQ
STANAG 4538: 75–4800 bps	Modem HF with ARQ
STANAG 4203	Interoperability requirements
ALE2G complies with MIL-STD-188-141B App. A	Automatic link establishment
ALE3G complies with STANAG 4538 (FLSU)	Automatic link establishment
FH complies with STANAG 4444	HF hoping
STANAG 5066	Data transmission in ARQ systems

It should be noted that RKP-8100 radio station, which has been used to verify radiocommunication in HF band is compliant with all of the above guidelines.

RESULTS OF RESEARCH ON THE IMPLEMENTATION OF NARROWBAND SERVICES

This chapter presents selected received signal strength indicator (RSSI — Received Signal Strength Indicator) test using the RKP-8100 radio station. RSSI expressed in dBm means the strength of the received signal.

Radio network was built based on narrowband RKP-8100 radio stations, used MANET protocol according to STANAG 4691 and hopping mode at 320 hop/s with TRANSEC algorithm.

Bellow selected research has been presented:
- BMS system tests at the Siemirowice airport;
- Jasmine command system tests at the BEMOWO PISKIE military compound;
- RKP-8100 tests in the HF band.

During the BMS system and Jasmine command system tests all nodes were equipped with RKP-8100 radio, operating in a 50 kHz channel with 50 W output power (for VHF band) and 20 W output power in a 3 kHz channel (for HF band). Synchronization between nodes in the network was carried out using the GPS module or alternatively — the OTA protocol (then necessary to select one node as a reference).

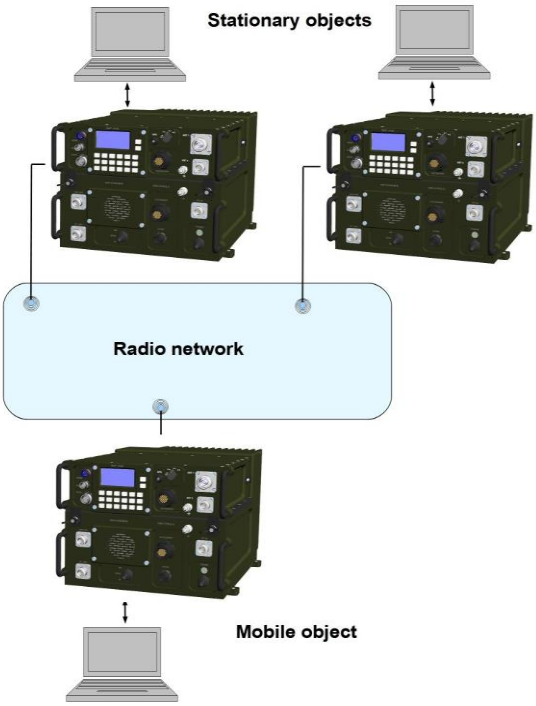

Fig. 2. Radio network based on the RKP-8100 radio

BMS system — Siemirowice [5]

During the tests a BFT (Blue Force Tracking) application was used to track a moving object, send system messages and text communication (chat). Along with the transmitted data, voice calls were also made using Vocoder MELP 2400.

Tests were carried out for two routes: east-west and north-south direction. Depending on terrain conditions, different maximum ranges for the presented modes of operation were obtained. Specialized software was used to allow automatic acquisition of data obtained based on the measurement of the signal level at the input of the receiver (RSSI).

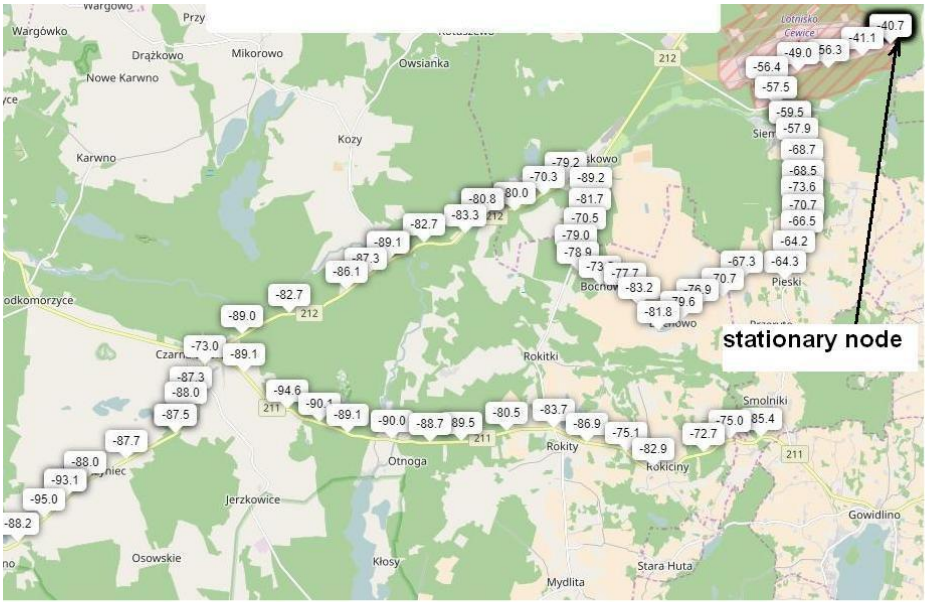

Fig. 3. Measurement RSSI when the moving object moves away from the stationary node; east-west direction [6]

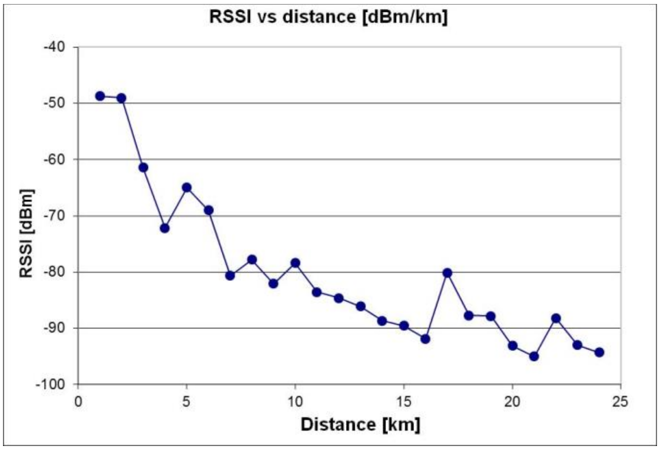

Fig. 4. Measurement RSSI vs distance; east-west direction

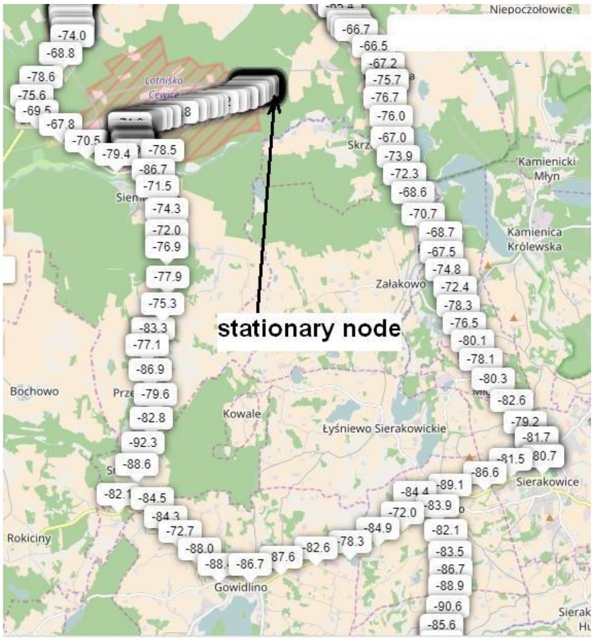

Fig. 5. Measurement RSSI when the moving object moves away from the stationary node; north-south direction [6]

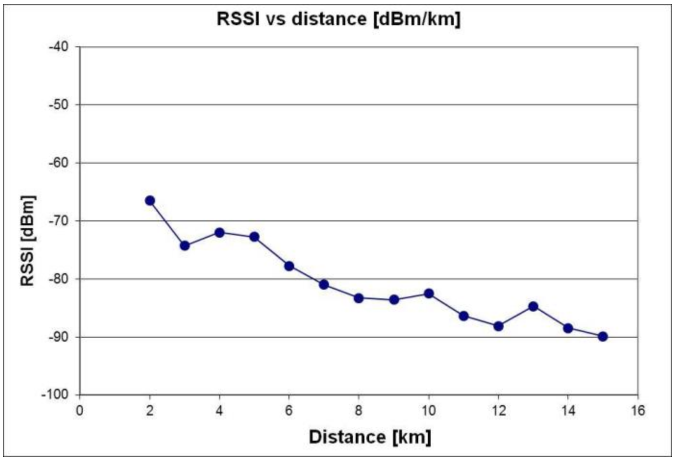

Fig. 6. Measurement RSSI vs distance; north-south direction

The maximum range obtained during tests was about 25km. The area was varied [7] and background noise was about –105 dBm (calculated for the 3 kHz band). Due to local interferences which after the mixing with heterodyne generates additional noise, receiver's parameters are degraded. This phenomenon, combined with the movement of the mobile station on a very topographically varied terrain [7] results in fadings with varying duration. The network reorganization time was just few seconds after which the connection resumed at the level of higher layers and the normal functioning of the system.

Jasmine command system tests

Bellow the route of the moving object is presented. As previously: two directions east-west and north-south.

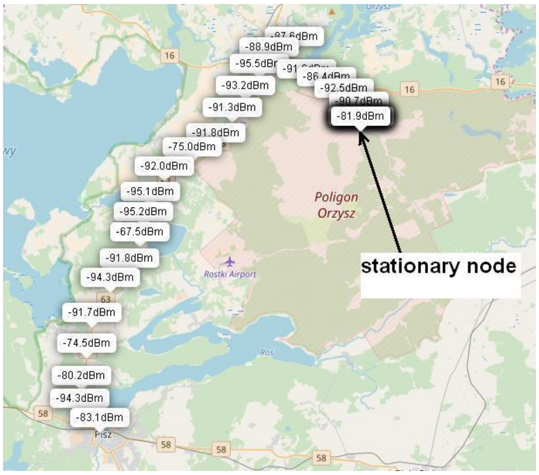

Fig. 7. Measurement RSSI when the moving object moves away from the stationary node; north-south direction [6]

Fig. 8. Measurement RSSI when the moving object moves away from the stationary node; east-west direction [6]

The configuration of the radio network was the same as in the case of tests in Siemirowice.

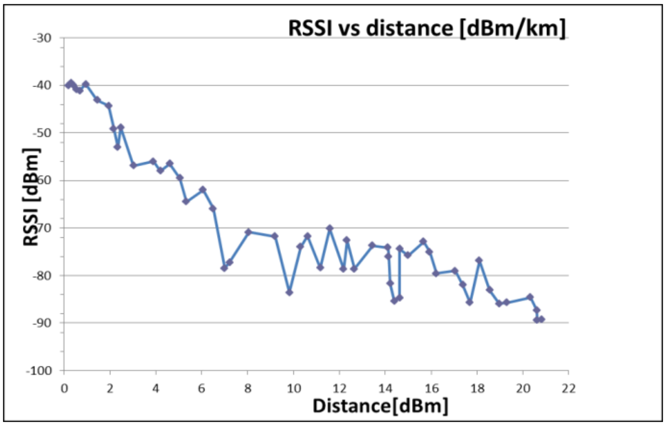

Fig. 9. Measurement RSSI vs distance; east-west direction

During the tests, system messages were sent and phone communication were made within the range of the radio with the use of Vocoder MELP 2400. The maximum range obtained during the tests was about 20 km. Due to terrain and mobility of the radio, communication was lost, while the MANET protocols and protocols of higher layers allowed for immediate synchronization of the radio, reorganization of the network and restoration of the system's full functionality.

RKP-8100 tests in the HF band {TA\l '**RKP-8100 tests in the HF band**'\s 'RKP-8100 tests in the HF band'\c 3} [5]

Tests of narrowband waveforms in the HF band were made using the RKP-8100 radio station in northern Poland. Communications were established between the mobile radio station RKP-8100 and four stationary radios located in points S1 to S4. In the communication planning process in HF range, specialized software using appropriate propagation models was used [1, 2].

S1 — stationary node equipped with RKP-8100 radio station and RF-5800H-MP radio station;
S2 — stationary node equipped with RKS-8000 radio station;
S3 — stationary node equipped with M3SR4100 radio station;
S4 — stationary node equipped with XK2500/2900 radio station.

The mobile node was moving in the east (points A–D), establishing communication with the stationary communication nodes HF. Rating scale for transmission:

<u>For analog phone transmission</u>
1: test was not carried out;
2: lack of perspicuity;
3: bad clarity signal (understanding only single syllables);
4: clarity signal (but in the noise);
5: full clarity signal.

<u>For data transmission</u>
D: test was not carried out;
C: no reception;
B: received message not consistent with the transmitted message;
A: received message consistent with the transmitted message.

Fig. 10. Localizations of the stationary nodes HF (S1–S4) and mobile node HF (A–D)

Due to the use of radio stations having an implemented set of waveforms in accordance with the latest standardization recommendations, it was possible to implement communication in all communication relationships provided in this scenario with the use of various communication systems working in HF band.

Tab. 2. Table of configuration of the test system and test results

Localization of the mobile node	**Localization of the stationary node (reference)**	**Condition of measurement**	**Quality of reception in the mobile node**	**Quality of reception in the stationary node**
ELBLĄG	GDYNIA CTM 1	Date & time 24.06.2015, 9:11 Mode: MIL-SDT-188-141 App. A — ALE 2G Phone analog (J3EU)	4	2
	GDYNIA CTM 2		4	4
	KOŁOBRZEG		5	4
DOBRE MIASTO	GDYNIA CTM 1	Date & time 24.06.2015, 13:16 Mode: MIL-SDT-188-141 App. A — ALE 2G Phone analog (J3EU)	2	2
	GDYNIA CTM 2		4	3
	BYDGOSZCZ		5	5
	KOŁOBRZEG		4	4
	WEJHEROWO		5	4
	WEJHEROWO	Phone analog STANAG 4198	5	4
	WEJHEROWO	Data transmission STANAG 4285	A	A
	WEJHEROWO	Data transmission MIL-SDT-188-110B	A	A
AUGUSTÓW	GDYNIA CTM 1	Date & time 24.06.2015, 8:12 Mode: MIL-SDT-188-141 App. A — ALE 2G Phone analog	4	4
	WEJHEROWO		4	3
	BYDGOSZCZ		5	4
	KOŁOBRZEG		4	5
	GDYNIA CTM 2		4	4
	GDYNIA CTM 2	Phone analog STANAG 4198	4	5
	GDYNIA CTM 1	Data transmission STANAG 4285	A	A
	GDYNIA CTM 2		A	A
	GDYNIA CTM 1	Data transmission MIL-SDT-188-110B	A	B
	GDYNIA CTM 2		A	A
	GDYNIA CTM 2	Mode: STANAG 4538 ALE 3G Phone analog	4	4
	GDYNIA CTM 2	Mode: STANAG 4538 ALE 3G Email using SMTP client	A	A
GIETRZWAŁD	GDYNIA CTM 1	Date & time: 24.06.2015, 16:17 Mode: STANAG 4538 ALE 3G Phone analog	3	3
	GDYNIA CTM 2		3	3
	GDYNIA CTM 1	Date & time: 24.06.2015, 16:17 Mode: STANAG 4538 ALE 3G Email using SMTP client	A	A

CONCLUSIONS

The article presents the requirements for modern radio communication using narrowband mode of operation in the VHF and HF range. Implementation of modern standardization recommendations allows to secure communication (immune to own and intentional interference) and significantly increases the radio network bandwidth (availability of a specific service). In HF range, due to the implementation of modern standardization recommendations, it was possible to realize radio communication using radio stations belonging to different manufacturers (heterogeneous networks). The presented research results made in various operational scenarios (land and sea) using the RKP-8100 radio show the correctness of the implementation.

In the long-term perspective, in connection with the participation of authors in the international NATO LoS CAT working group, the main effort will be directed to the development and implementation of NBWF waveforms (frequency range 30–512 MHz) for coalition activities.

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UŻYCIE NOWYCH WAVEFORMÓW WĄSKOPASMOWYCH W CELU ZAPEWNIENIA PRAWIDŁOWEJ PRACY SYSTEMÓW DOWODZENIA I ŁĄCZNOŚCI

STRESZCZENIE

Jednym z głównych wyzwań stawianych współczesnym systemom dowodzenia i łączności działającym na rzecz zapewnienia bezpieczeństwa i obronności morskiej jest realizacja odpowiedniej jakości usług podstawowych. Specyfika działania systemów morskich wymusza wykorzystanie wąskopasmowych środków łączności radiowej pracujących w zakresie KF i UKF. Odpowiednie waveformy wąskopasmowe pozwalają na realizację transmisji IP. W artykule przedstawione zostały wymagania stawiane środkom łączności radiowej KF i UKF w celu zapewnienia realizacji transmisji IP. Opisano podstawowe właściwości waveformów wąskopasmowych KF i UKF oraz sposób ich użycia w systemach morskich (scenariusze operacyjnego wykorzystania). Przedstawione zostały także wyniki badań eksperymentalnych (realizacja usług wąskopasmowych — głos i dane) oraz dalsze kierunki badań ze szczególnym uwzględnieniem udziału autorów artykułu w grupach roboczych NATO związanych z opracowaniem waveformów wąskopasmowych NBWF do łączności koalicyjnej.

Słowa kluczowe:

LOS, BLOS, NBWF, RKP-8100, RSSI, BMS, VHF, UHF, HF.

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